ESTIMATED GROUNDWATER FLOW CAPTURED BY THE FUNNEL-AND-GATE SYSTEM LEHIGH CEMENT COMPANY CLOSED CKD PILE METALINE FALLS, WASHINGTON

Objective

The preliminary calculations described in this document are intended to estimate flowrate of groundwater that will be captured by the funnel-and-gate system, which is part of the Remedy. The approximated flowrate of groundwater captured by the Remedy can be estimated as the groundwater intercepted by the groundwater barriers walls and French drain.

Calculation Approach

The approach used for calculating the groundwater flow to the Remedy included:

- Evaluate historical groundwater potentiometric surface maps to develop an understanding of the groundwater flow direction and gradient. The November 2004 data, which are representative of Site conditions, were used in this analysis;

- Evaluate the locations of nearby groundwater wells and boreholes with groundwater surface elevation data (November 2004) and aquitard elevation data (from borehole logs) that can be used to estimate groundwater flow;

- Generate two cross-sections based on the information from the first two bullets that are approximately perpendicular to groundwater flow (see Attachment 1). Two cross-sections were used to calculate separate flowrates for comparison purposes; and

- Apply Darcy's law for steady flow along a flow line (i.e., through the two cross-sections described in the previous bullet). This flow line

represents an estimate of the groundwater that will be captured by the funnel-and-gate system for treatment by the Remedy.

Analysis

Cross-sections 1 and 2 are shown on Attachment 1. Approximate characteristics of the two cross sections are:

Length, L_{total} = 750 ft
Nearby groundwater gradient, i = 0.036 ft/ft

Each of the two cross-sections was drawn in the immediate vicinity of five existing groundwater wells. The cross-sections were extended to the approximate lateral extant of the zone that will be captured by the funnel-and-gate system of the Remedy. Sectional end points were assigned. The distance between the groundwater surface elevation and aquitard elevation at each location was taken to be representative of the saturated thickness of the aquifer. The saturated thicknesses were used in combination with the lengths of the cross-section to estimate the approximate flow area for each cross-section. The flow area, cross-section length, and gradient were used to estimate the flowrate according to Darcy's law, Equation 1.

$$Q = K \cdot A \cdot i \quad (1)$$

Where:
Q = Groundwater volumetric flowrate
K = horizontal hydraulic conductivity
A = area normal to groundwater flow (flow area)
i = nearby groundwater gradient

Flow areas were calculated using available lithologic information from borings that were installed approximately along the cross-section alignment. The total cross-section flow area was calculated by adding the flow areas between consecutive borings along the cross-section. The flow area was calculated between consecutive data points using a trapezoidal area equation (Equation 2).

$$A_{ij} = \frac{l}{2}(h_i + h_j) \quad (2)$$

Where:
A_{ij} = flow area between consecutive data points
l = distance between consecutive data points
h_i = saturated thickness at i
h_j = saturated thickness at j

The tables below summarize the calculation procedure.

Cross-section 1:

Point	Water Level (ft AMSL)	Aquitard Elevation (ft AMSL)	h_i (ft)	l (ft)	A_{ij} (ft^2)
End			7.40		
MW8	2029.28	2019.80	9.48	100	845
PM14	2028.62	2017.57	11.05	130	1335
MW9	2028.70	2015.34	13.36	70	855
PM2	2024.10	2021.45	2.65	100	800
PM18	2021.20	2013.82	7.38	210	1050
End			13.00	140	1430
				Total (A_1)	**6315**

Cross-section 2:

Point	Water Level (ft AMSL)	Aquitard Elevation (ft AMSL)	h_i (ft)	l (ft)	A_{ij} (ft^2)
End			15.70		
MW7	2030.37	2016.19	14.18	40	600
PM8	2025.41	2020.45	4.96	250	2390
PM6	2024.84	2020.74	4.10	100	455
PM20	2020.77	2017.09	3.68	140	545
PM19	2020.21	2009.13	11.08	180	1330
End			12.72	40	480
				Total (A_2)	**5800**

Existing horizontal hydraulic conductivity values from the immediate vicinity of cross-sections 1 and 2 are summarized below.

K_{PM-16} = 1.74 x 10^{-2} ft/ min to 6.60 x 10^{-2} ft / min [GeoSyntec, 2005]

$K_{MW-7} = 1.67 \times 10^{-2}$ ft/ min [Dames and Moore, 1993]
$K_{MW-8} = 1.68 \times 10^{-2}$ ft/ min [Dames and Moore, 1993]

Results

Using Equation 1, the ranges of estimated groundwater flow through Section 1 and Section 2 were calculated according to the procedures described in this document. The results are summarized in tables below.

Cross-Section 1 (A = 6,315 ft^2)

Range	K (ft/min)	Q (ft^3/min)	Q (gal/min)	Q (ft^3/s)
High	6.60×10^{-2}	15	110	0.25
Low	1.67×10^{-2}	3.9	28	0.07

Cross-Section 2: (A = 5,800 ft^2)

Range	K (ft/min)	Q (ft^3/min)	Q (gal/min)	Q (ft^3/s)
High	6.60×10^{-2}	14	100	0.23
Low	1.67×10^{-2}	3.5	26	0.06

Thus, according to the preliminary calculations shown in this document, the estimated groundwater flowrate that will be captured by the funnel-and-gate system is between 3.5 and 15 cubic feet per minute.

Limitations and Assumptions

The approach presented in this document is an estimation procedure to calculate the groundwater flow that will be intercepted by the Remedy funnel-and-gate system. The assumptions and limitations associated with the estimation procedure include:

- Horizontal hydraulic conductivity is uniform throughout the entire cross-section. The horizontal hydraulic conductivities used in this analysis were selected from groundwater wells in the vicinity of the cross-sections (see Appendix A of the Engineering Design Report). Additionally, boring logs indicate that subsurface materials are

similar throughout the cross-sectional alignment, consisting of interbedded silty gravels, poorly-graded gravels, and sandy silts;

- The flow areas between consecutive data points were calculated assuming that the flow areas are trapezoidal. This implies that the slope of the groundwater surface elevations and aquitard elevations between data points is linear;

- Water flowing through the cross-sections will be intercepted by the French drain and groundwater cut off walls, and that no flow will bypass the funnel-and-gate system;

- The analysis used here assumes that groundwater conditions (e.g., gradient, groundwater table elevation, etc.) will not be affected by the Remedy. A more sophisticated analysis using a dynamic model may be used in future calculations to refine the estimated groundwater flowrate that will be captured by the funnel-and-gate system; and

- The methodology described in this document is an estimation of the hydraulic conditions at the Site based on existing data. The groundwater surface elevations used herein are from one point in time and likely fluctuate due to factors such as seasonality, infiltration, and year-to-year variability. The results presented here are useful for evaluating basic feasibility considerations and Remedy sizing calculations.

APPENDIX B, ATTACHMENT 1

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